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WATER MOVEMENTS IN THE NANTICOKE REGION OF LAKE ERIE 1976

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WATER MOVEMENTS IN THE
NANTICOKE REGION
OF
LAKE ERIE
1976

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Toronto, Ontario
August 1978

WATER MOVEMENTS IN THE NANTICOKE REGION OF LAKE ERIE 1976

SUMMARY

The on-going investigation of water movements in the vicinity of the recently constructed Stelco Dock, in the Nanticoke region of Lake Erie, continued during 1976. The magnitude of currents was generally slower in 1976 than in the previous years; probably due to the proximity of Stelco Dock to the instrument locations. The resultant current speed ranged from 0.4 to 1.7 cm.s^{-1} with persistence factors of 0.23-0.69. The direction of net currents near the dock indicated the possibility of a flow pattern or current field convergence. The current magnitudes were temporally homogenous during 1976 while the presence of the dock redirected or changed the local direction.

Spectral analysis of the data showed the presence of some lakewide effects in the nearshore zone after their absence in the early post-operational period (1973-74). No significant coherences were observed between the currents on either side of the dock.

THE
WATER MOVEMENTS IN THE NANTICOKE REGION OF LAKE ERIE 1976

INTRODUCTION

As part of the on-going investigations by the Nanticoke Environmental Committee (NEC), the water movements study was continued offshore of Nanticoke, Lake Erie (see Figure 1) during 1976. Two Geodyne type self-recording current instruments (without temperature sensors) were operated, from May 20 to October 19, 1976, one on either side of the recently constructed Stelco dock .

The purpose of the present study was to compare the results with the previous water movements investigations (NEC, 1973; Kohli, 1974, 1976 and 1977 - see Figure 2 for the previous study locations) in the area and determine any trends or effects due to the increased industrial activity in the region.

The Stelco dock (see Figure 3) construction commenced in April 1975 and was completed in October 1976. The dock extends 1190 m into the lake and comprises three sections: a 320 m nearshore bridge; a 420 m causeway; and a 450 m wharf including the offshore bridge. To facilitate construction, a temporary causway was built at the site of the nearshore bridge in April 1975 (Camberlain, 1978). This blocked the water movements, accumulated sediments and led to their resuspension. The temporary causway was removed in October 1976 to allow the free movement of water, fish and sediments along the shoreline. Camberlain (1978) showed that while the turbidity increased near the dock during construction, it decreased at the completion of construction indicating no permanent effect of the dock on turbidity.

All data collected were numerically smoothed (see Appendix I) and then partitioned into monthly records for comparison with the previous results. Each data set was subjected to statistical analysis to determine the spatial and temporal characteristics of water movements. Spectral analysis of the data identified the physical mechanisms responsible for the coastal motions.

DISCUSSIONS

The resultant currents are vectorially represented in Figure 1, indicating net water movements towards the south or away from the dock except during June and October 1976 at the easterly location (175). Such water movement patterns may be due to the proximity of the Stelco dock to the study sites. Careful examination of the resultant currents (see Figure 1) shows that they were approximately in opposite directions on either side of the dock during July and August 1976. This may be due to a flow pattern or current field convergence.

Statistical results of the currents at both locations are summarized in Table 1. The resultant currents ranged from 0.4 to 1.7 $cm.s^{-1}$ while the arithmetic average speed of currents varied from 1.1 to 4.0 $cm.s^{-1}$. The maximum current speed recorded during the study period (May to October 1976) was 18.4 $cm.s^{-1}$. The persistence factors ranged between 0.23 and 0.69. During 1975, the currents were generally faster than the earlier years (Kohli, 1977). The resultant currents during 1975 were from 0.2 to 11.3 $cm.s^{-1}$ while the arithmetic average speed ranged between 3.7 and 13.8 $cm.s^{-1}$ and the maximum current speed recorded was 56.9 $cm.s^{-1}$. During 1974, the resultant currents varied from 0.9 to 5.8 $cm.s^{-1}$ and the arithmetic average speed ranged between 2.5 and 7.0 $cm.s^{-1}$ (Kohli, 1976).

The mean speed of all arithmetic average currents during 1976 was 2.7 $cm.s^{-1}$ with the standard deviation of 1.0 $cm.s^{-1}$. Thus the monthly arithmetic average currents remained within one standard deviation from the mean indicating that the current magnitudes were maintained during the present study. Data on current directions show the dock is redirecting or changing local direction. The effect of the dock on water movements will be studied in more detail during 1978 by operating current instruments under the nearshore and offshore bridges of the dock. In other words, the current magnitudes were temporally homogenous during the present study.

Table 2 presents some comparative characteristics of water movements of the study sites during 1968-76. The study locations of the previous years appear in Figure 3. In five sixths of the records (1968-76), currents were parallel to the resultant for more than 30% of the time. As a measure of comparison, distances travelled along the resultant direction in 10 h (arbitrarily chosen) were computed and are listed in Table 2. An average of 1.3 km distance was travelled in 10 h (for the present study) with a standard deviation of 0.4 km (average/standard deviation = 3.3). This represented the second lowest distances travelled, lowest being 0.8 km in 1973. The slower water movements of 1976 may be attributed to the close proximity of the Stelco docks (a physical barrier) to the study locations. Water movements away from the physical barrier of the Stelco dock, were not investigated.

Figure 4 and Table 3 present the percentage of time the net water movements were in a major compass direction. During 1976, the net water movement was 30% from the West and 40% from the North (probably due to the study locations being in close proximity of the Stelco dock). However, for the total period of 1968-76, the net movements were 57% of the time from the west and 23% of the time from the east. The predominant directions of currents during 1976 was from the north while it remained parellel to the shoreline (east-west) for 80% of the time during 1968-76.

Average monthly wind speed at Simcoe, Ontario during 1968-76 presented in Figure 5, shows no significant differences over the years. Therefore the slower current speeds for the present investigation are not correlated to the wind speed.

Autospectra

A summary of major spectral periods for currents (along the north-south and east-west directions) is presented in Table 4. Rockwell (1966) computed the Merian period as 16.8 h and the first five modes of longitudinal free oscillations of Lake Erie as 14.1, 8.9, 5.7, 4.1 and 3.7 h respectively. Merian period may be related to the observed period of 17.1 h in the east-west direction during June at site 176. The observed period of 13.3 h, at site 175 in the north-south direction during June and at location 176, in the east-west direction during July, is close to the fundamental period of 14.1 h. The semi-diurnal period of 12.0 h at location 175 during May in the east-west direction may be attributed to the lunar tides. Values close to the computed period of Lake Erie (Rockwell, 1966) were observed at both study sites (see Table 4). Rockwell (1966) also computed the fundamental period of Long Point Bay as 2.5 h and this period and values close to it were generally observed at both locations (see Table 4). The closeness of the observed periods (Table 4) to the theoretically computed modes (Rockwell, 1966) confirms the presence of lakewide and baywide effects on currents at the study locations. The lowest observed frequencies of 2.3 and 2.2 h are attributed to the local shoreline effects.

A comparison of significant spectral periods at all study locations offshore of Nanticoke, Lake Erie since 1968 is presented in Table 5. The range of spectral periods during 1976 was similar to that in 1975. Diurnal and lakewide periodicities were predominant during the pre-operational period of 1968-69. However, the local periodocities of less than 3 h and the lower modes of Lake Erie were predominant in the post operational period of 1973-76. This indicates the importance of the local phenomenon in the coastal regions of Lake Erie (offshore of Nanticoke) Some longor periodicities were observed recently (1975-76) indicating the presence of the lakewide effects after their absence in an early post-operational period (1973-74) - see Table 5. If their presence persists in the future, it would be of some importance to long term trends in water movements.

During 1976, currents were cross-correlated on both sides of the dock but no significant coherences were observed. This may be due to the physical barrier between the two study locations.

CONCLUSIONS

The currents on both sides of the Stelco dock were relatively slower during 1976 and this was probably due to the proximity of the physical barrier near the study area . It is not known if the slower currents prevailed in the open coastal areas, offshore from Nanticoke during the year. The resultant current speed ranged from 0.4 to 1.7 cm. s^{-1} with persistence factors of 0.23-0.69. During 1976, the maximum current speed recorded was 18.4 cm. s^{-1} while the arithmetic average speed of currents varied from 1.1 to 4.0 cm.s^{-1} for the months of May to October. During the present study, the net currents came from north, west and east for 40, 30 and 20% of the records respectively i.e. the resultant currents remained parallel to the dock for 40% of the records and paralled to the east-west shoreline for 50% of the records. However, during 1968-76, the resultant currents were along the east-west axis for 80% of the records.

The spectral analysis of the currents confirmed the importance of local phenomenon on the water movements in the coastal regions, offshore of Nanticoke.

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TABLE 1: Statistical Summary of Current Meter Operations, Offshore of Nanticoke, Lake Erie, 1976

	LOCATION									
	175						176			
	PERIOD									
	May	Jun	Jul	Aug	Sep	Oct	May	Jun	Jul	Aug
Resultant direction coming from 0^{o} as North	261	139	283	312	346	40	345	43	83	69
Resultant Speed (cm.s^{-1})	1.69	1.63	0.79	0.70	0.99	1.34	0.77	0.38	1.15	1.25
Average Speed (cm.s^{-1})	2.45	3.22	3.49	2.82	4.04	3.78	1.13	1.64	2.02	1.95
Maximum Speed (cm.s^{-1})	7.94	12.88	12.75	10.44	18.44	13.19	6.25	11.25	15.69	14.88
Persistence Factor	0.69	0.50	0.23	0.25	0.24	0.35	0.68	0.23	0.57	0.64
Percentage of Negligible* speed (% of recording period)	14	16	6	15	6	6	34	29	20	28
Percentage of time going in direction of resultant	40	35	18	18	18	20	45	8	34	24
Total No. of Readings	792	2160	2232	2232	2160	1341	792	2160	2232	2232
Interval of Readings (mins)	20	20	20	20	20	20	20	20	20	20

*<0.31 cm.s^{-1}

TABLE 2

COMPARISON OF WATER MOVEMENT RESULTS WITH PREVIOUS STUDIES, NANTICOKE REGION, LAKE ERIE

Location Code	Period	Resultant Direction Coming from 0° as North	Percentage of Time Going			Percentage of Negligible (<0.3 cm.s^{-1}) Currents	Max. Percentage Occurrence in any Speed Class Range (except negligible)	Mean of Speed Class Range with Max. Occurrence (cm.s^{-1})	Mean Speed in direction of Resultant (cm.s^{-1})	Distance Travelled Along Resultant (in 10 h) (km)	Mean of Distance Travelled (in 10 h) (km)		Standard Deviation of Distance Travelled (km)	
			In direction of Resultant	Opposite to Resultant	Along the Resultant Axis									
022	Aug 68	262	40	14	54	15	27	4.5	6.2	2.2	2.62	2.21	1.29	1.18
022	Sep 68	277	45	23	68	10	33	4.5	5.1	1.8				
023	Sep 68	277	52	11	63	54	25	1.7	2.7	1.0				
021	Oct 68	272	44	26	70	18	25	4.5	7.2	2.6				
022	Oct 68	271	59	17	76	10	20	4.5	9.8	3.5				
023	Oct 68	268	52	11	63	31	22	1.7	6.2	2.2				
021	Nov 68	298	36	26	62	28	27	4.5	3.7	1.3				
022	Nov 68	273	85	0	85	1	23	4.5	13.2	4.7				
023	Nov 68	273	59	22	81	21	20	4.5	12.0	4.3				
021	May 69	256	43	13	56	36	21	1.7	6.2	2.2	1.95		0.96	
024	May 69	278	50	16	66	31	16	7.5	9.0	3.2				
021	Jun 69	74	33	28	61	38	25	1.7	3.1	1.1				
022	Jun 69	255	24	9	33	24	25	4.5	5.0	1.8				
024	Jun 69	276	38	9	47	28	21	4.5	9.6	3.5				
021	Jul 69	67	22	15	37	29	29	1.7	3.5	1.3				
022	Jul 69	15	54	1	55	25	22	4.5	4.6	1.7				
024	Jul 69	18	12	7	19	35	22	1.7	2.2	0.8				
021	Jan 70	255	40	25	65	41	20	4.5	6.8	2.5	1.45		1.48	
021	Feb 70	69	33	12	45	74	10	4.5	1.1	0.4				
025	Jul 73	16	16	7	23	19	23	1.7	3.5	1.3	0.79		0.42	
026	Jul 73	125	10	4	14	57	15	1.2	1.6	0.6				
026	Aug 73	77	28	11	39	74	15	1.2	0.7	0.3				
026	Sep 73	107	25	12	37	48	15	3.0	2.7	1.0				
028	Apr 74	306	50	1	51	15	16	1.5	5.8	2.1	2.23		1.35	
028	May 74	300	30	9	39	4	15	4.0	6.8	2.4				
028	Jun 74	305	42	8	50	30	20	1.7	4.6	1.7				
028	Jul 74	287	18	13	31	3	17	3.0	15.4	5.5				
027	Aug 74	35	27	15	42	18	19	1.5	4.1	1.5				
027	Sep 74	295	17	5	22	15	21	1.5	2.2	0.8				
027	Oct 74A	245	35	5	40	6	31	1.5	5.0	1.8				
027	Oct 74B	255	26	7	33	10	22	1.5	4.4	1.6				
028	Oct 74	301	49	2	51	2	21	3.0	9.7	3.5				
028	Nov 74	255	26	10	36	10	36	1.7	3.8	1.4				
171	May 75	204	17	6	23		49	11.0	13.0	4.7	3.49		1.54	
172	May 75	90	40	20	60		17	4.5	7.9	2.8				
173	May 75	229	24	12	36	11	19	1.7	8.4	3.0				
174	May 75	264	37	5	42	9	13	1.5	6.9	2.5				
171	Jun 75	157	8	7	15		23	12.5	13.8	5.0				
172	Jun 75	113	15	19	34		15	5.0	9.0	3.2				
173	Jun 75	224	36	7	43	3	12	5.0	14.2	5.1				
172	Jul 75	284	48	0	48		4	2.5	2.3	0.8				
174	Jul 75	276	52	3	55	6	13	3.5	4.6	1.7				
171	Sep 75	98	44	18	62		16	7.0	12.5	4.5				
172	Sep 75	98	58	15	73		17	5.0	14.2	5.1				
173	Sep 75	271	41	5	46	7	24	3.0	5.2	1.9				
174	Sep 75	276	49	15	64	3	17	3.0	7.5	2.7				
171	Oct 75	100	31	23	54		15	7.0	16.0	5.8				
172	Oct 75	101	50	17	67		22	7.0	15.2	5.5				
173	Oct 75	260	29	9	38	11	14	1.5	6.4	2.3				
174	Oct 75	290	25	13	38	5	21	3.0	7.2	2.6				
171	Nov 75	323	46	2	48		18	2.5	5.2	1.9				
172	Nov 75	90	71	8	79		21	10.5	17.1	6.2				
173	Nov 75	270	44	4	48	6	26	1.2	7.5	2.7				
174	Nov 75	290	35	6	41	5	30	1.7	12.5	4.5				
175	May 76	261	40	0	40	14	22	1.5	3.0	1.1	1.31		0.40	
176	May 76	345	45	9	54	34	25	0.7	1.5	0.5				
175	Jun 76	139	35	5	40	16	24	9.0	4.5	1.6				
176	Jun 76	43	8	14	22	30	19	0.7	2.8	1.0				
175	Jul 76	283	18	8	26	6	23	9.0	4.0	1.4				
176	Jul 76	83	34	13	47	20	20	1.5	4.1	1.5				
175	Aug 76	312	18	7	25	15	19	8.0	3.4	1.2				
176	Aug 76	69	24	12	36	28	20	1.5	3.4	1.2				
175	Sep 76	346	18	10	28	6	30	3.0	4.6	1.7				
175	Oct 76	40	20	10	30	6	32	9.5	5.4	1.9				

Table 3 Net Water Movement Directions 1968-76

Coming From

Year	Total No. of Water Movement Records	South		West		North		East	
		# of Times	% of Total	# of Times	% of Total	# of Times	% of Total	# of Times	% of Total
1968	9			9	100				
1969	8			4	50	2	25	2	25
1970	2			1	50			1	50
1973	4					1	25	3	75
1974	10			9	90	1	10		
1975	22	3	14	11	50	1	4	7	32
1976	10	1	10	3	30	4	40	2	20
1968-1976	65	4	6	37	57	9	14	15	23

TABLE 4 : Summary of Major Spectral Periods (hours),
80 Percent Confidence Level
Nanticoke, Lake Erie, 1976

Location	Month 1976	North-South	East-West
175	May	None	12.0,6.3,5.0
	Jun	13.3,4.0,3.1,2.2	6.3,4.1,2.7**
	Jul	5.7,3.9,3.2,2.3,2.2	2.8
	Aug	None	3.5,2.1
	Sep	6.7,5.0,3.9,3.2,2.3	None
	Oct	6.3*	6.3,4.1,2.2
176	May	7.5	10.0,8.0,4.3
	Jun	2.7,2.5,2.3**	17.1,2.7,2.3
	Jul	2.7**,2.2	13.3*,4.4,4.0,2.3
	Aug	7.5,4.8,3.6**,2.7	4.1

* 95% confidence level
** 99% confidence level

TABLE 5: COMPARISON OF SPECTRAL RESULTS WITH PREVIOUS STUDIES, NANTICOKE, LAKE ERIE

SIGNIFICANT SPECTRAL PERIODS (HOURS)

Location (year)	MAY		JUN		JUL		AUG		SEP		OCT		NOV	
	N-S	E-W	N-S	E-W	N-S	E-W	N-S	E-W	N-S	E-W	N-S	E-W	N-S	E-W
022 (1968)							20.0,14.0 9.0	15.0,11.0 6.0	None	22.0,13.0 7.8	None	None	16.0	20.0,12.0 7.6,6.0
023 (1969)									None	24.0,11.0 7.4,4.5	None	11.0		
021 (1969)	20.0	20.0,13.7			None	10.9								
022 (1969)			None	17.1,12.0										
024 (1969)	None	20.0,10.0	None	17.1	17.1	None								
025 (1973)					6.3,3.2	10.9,2.9								
026 (1973)					3.8,3.2 2.4	8.6,5.7 2.7	None	4.1,2.3	None	None				
027 (1974)							12.0,3.5	None	None	9.2,4.8, 3.9,3.1, 2.4	5.2,3.5	3.2	10.9,8.6, 4.8	12.0,8.6, 4.0
028 (1974)	None	2.4	15.0,4.0 2.9,2.5	15.0,2.6	2.9	4.3					6.3,5.0, 4.1	2.7		
171 (1975)	4.1,3.1, 2.3	4.4,2.7, 2.2	5.5,2.1	8.6,6.7					9.2,6.7, 5.5,4.1, 3.8,3.1, 2.2	6.7,2.3	4.6,2.3	3.0	5.0	6.0,4.4, 3.0,2.5, 2.3
172 (1975)	24.0,5.5, 4.0,2.6, 2.3,2.0	None	7.5,4.6, 4.0,3.0	2.3	3.8,3.3, 2.7,2.2	2.1			5.2,3.4, 2.1	2.1	7.5	None	4.4,2.9	None
173 (1975)	8.6,2.5, 2.3	10.9,4.8, 3.0	10.9,5.7, 4.4,3.2	10.9					12.0,3.6, 3.2,2.9, 2.1	4.6,3.6 2.4	9.2,3.3, 2.9	4.0	None	2.3
174 (1975)	4.6,2.0	4.6,3.5, 2.4	None	None	7.1,4.4, 3.4,2.9, 2.0	8.6,4.8, 3.1,2.7, 2.1			10.9,4.4 3.6,2.2	13.3,10.0 2.1	None	6.3,3.6	5.5,3.4 2.9,2.6	4.9,3.7 3.0
175 (1976)	None	12.0,6.3 5.0	13.3,4.0 3.1,2.2	6.3,4.1 2.7	5.7,3.9 3.2,2.3, 2.2	2.8	None	3.5,2.1	6.7,5.0 3.9,3.2 2.3	None	6.3	6.3,4.1, 2.2		
176 (1976)	7.5	10.0,8.0 4.3	2.7,2.5, 2.3	17.1,2.7, 2.3	2.7,2.2	13.3,4.4, 4.0,2.3	7.5,4.8, 3.6,2.7	4.1						

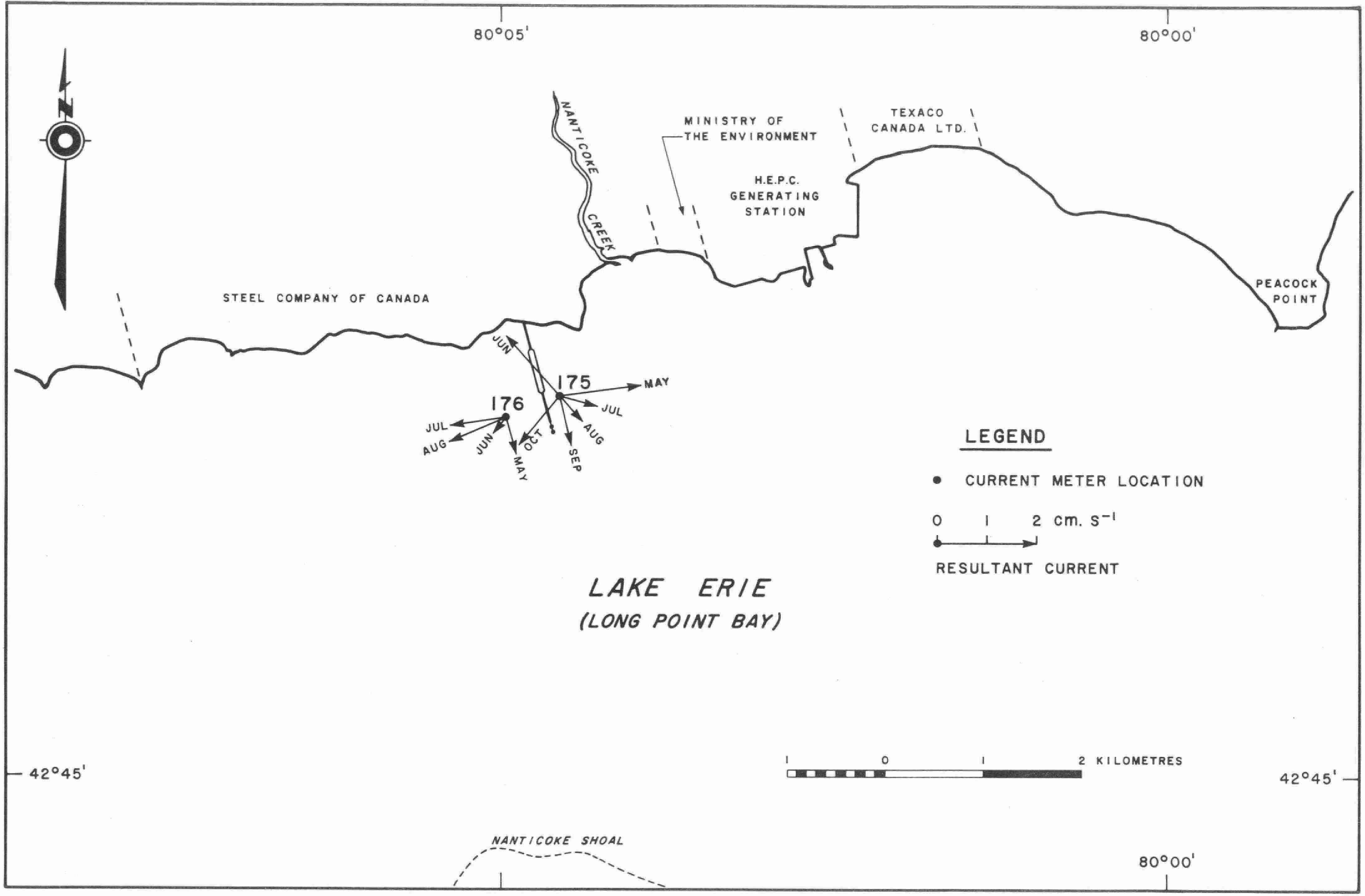


FIGURE 1 - RESULTANT CURRENTS OFFSHORE OF NANTICOKE, LAKE ERIE, 1976.

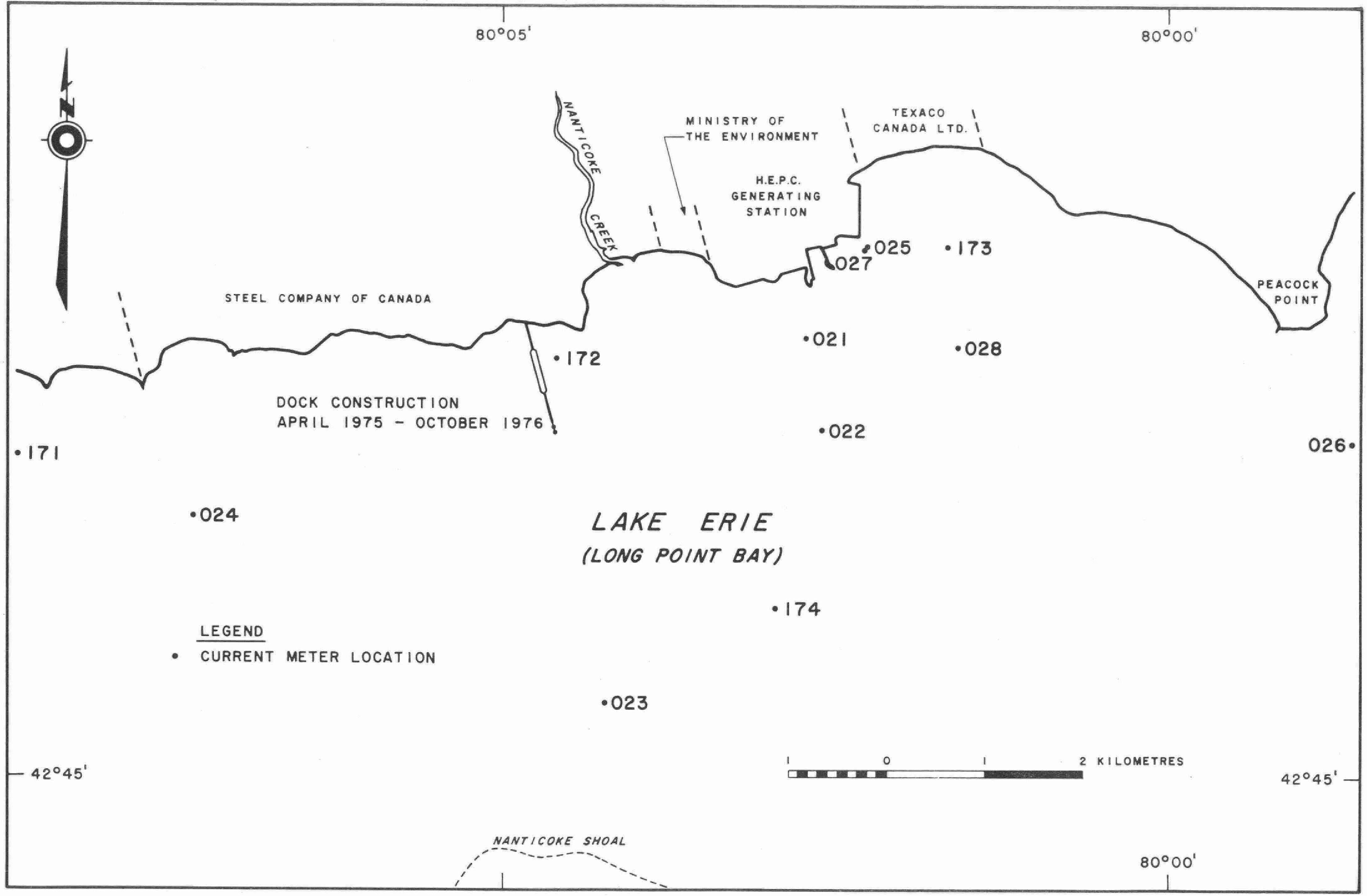
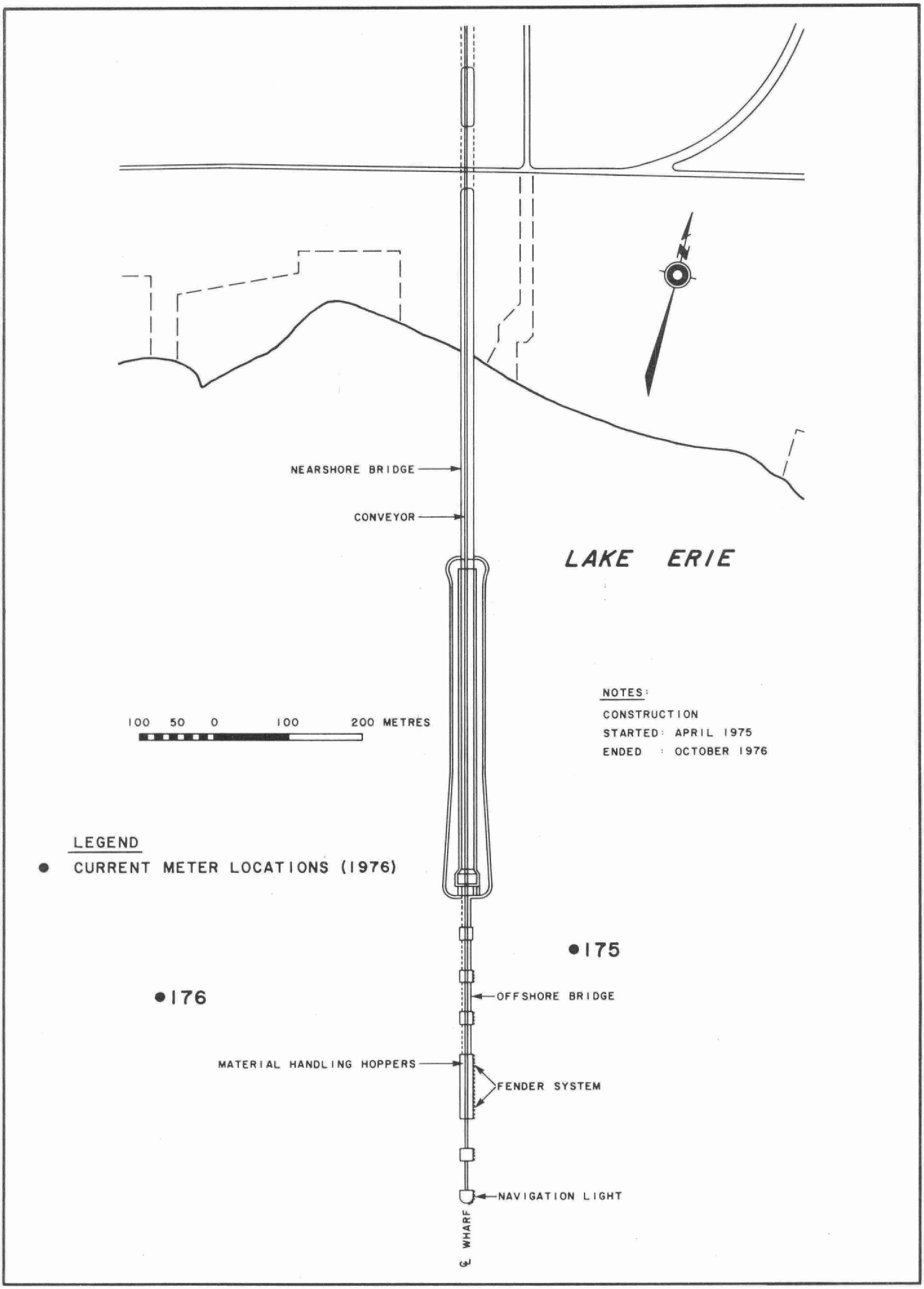


FIGURE 2 - STUDY LOCATIONS FOR PREVIOUS YEARS (1968-75) OFFSHORE OF NANTICOKE, LAKE ERIE



NOTES:
CONSTRUCTION
STARTED: APRIL 1975
ENDED : OCTOBER 1976

LEGEND
● CURRENT METER LOCATIONS (1976)

FIGURE 3 - STELCO DOCK, OFFSHORE OF NANTICOKE, LAKE ERIE.

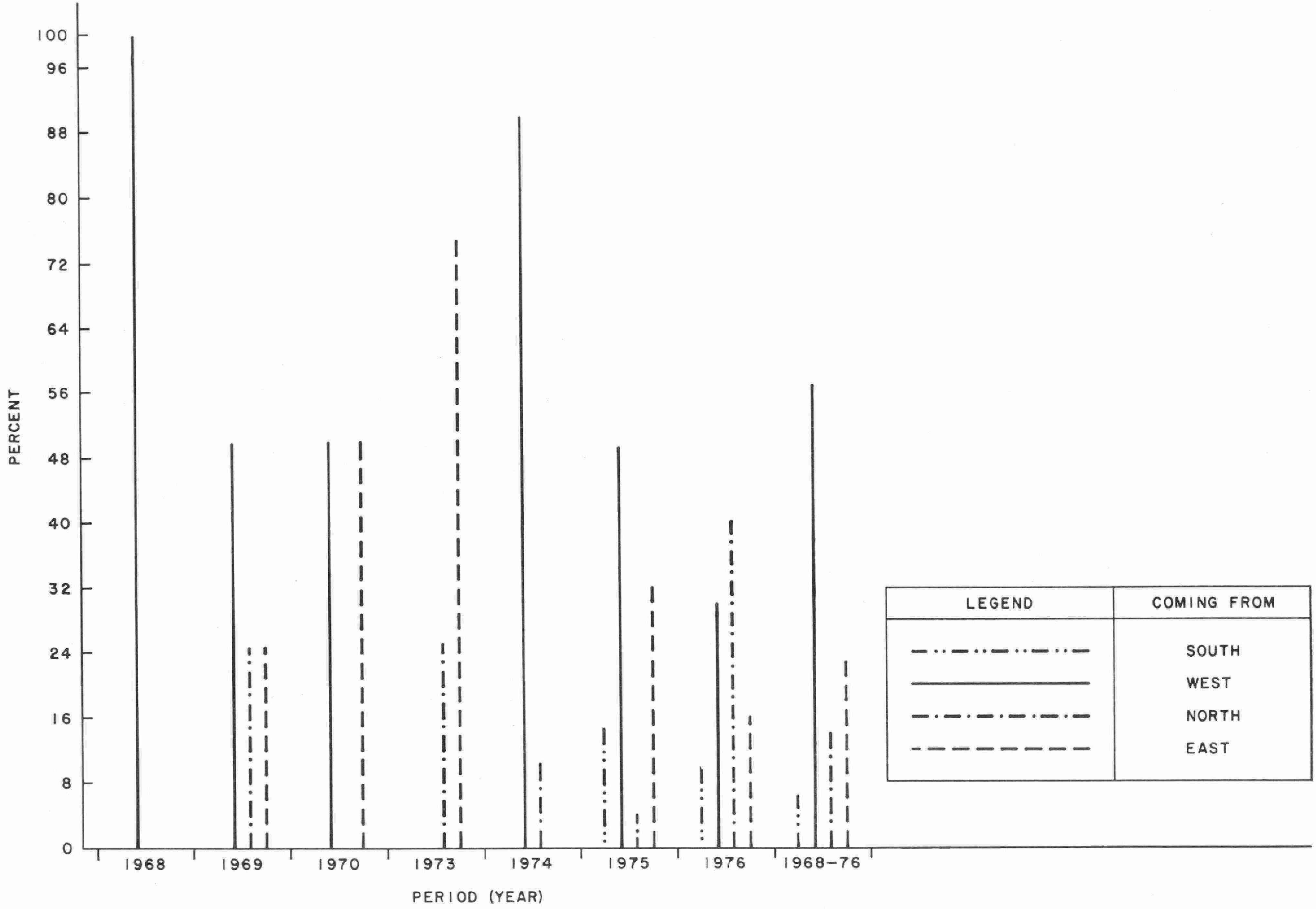


FIGURE 4 - NET WATER MOVEMENT DIRECTIONS (COMING FROM) OFFSHORE OF NANTICOKE, LAKE ERIE 1968–76

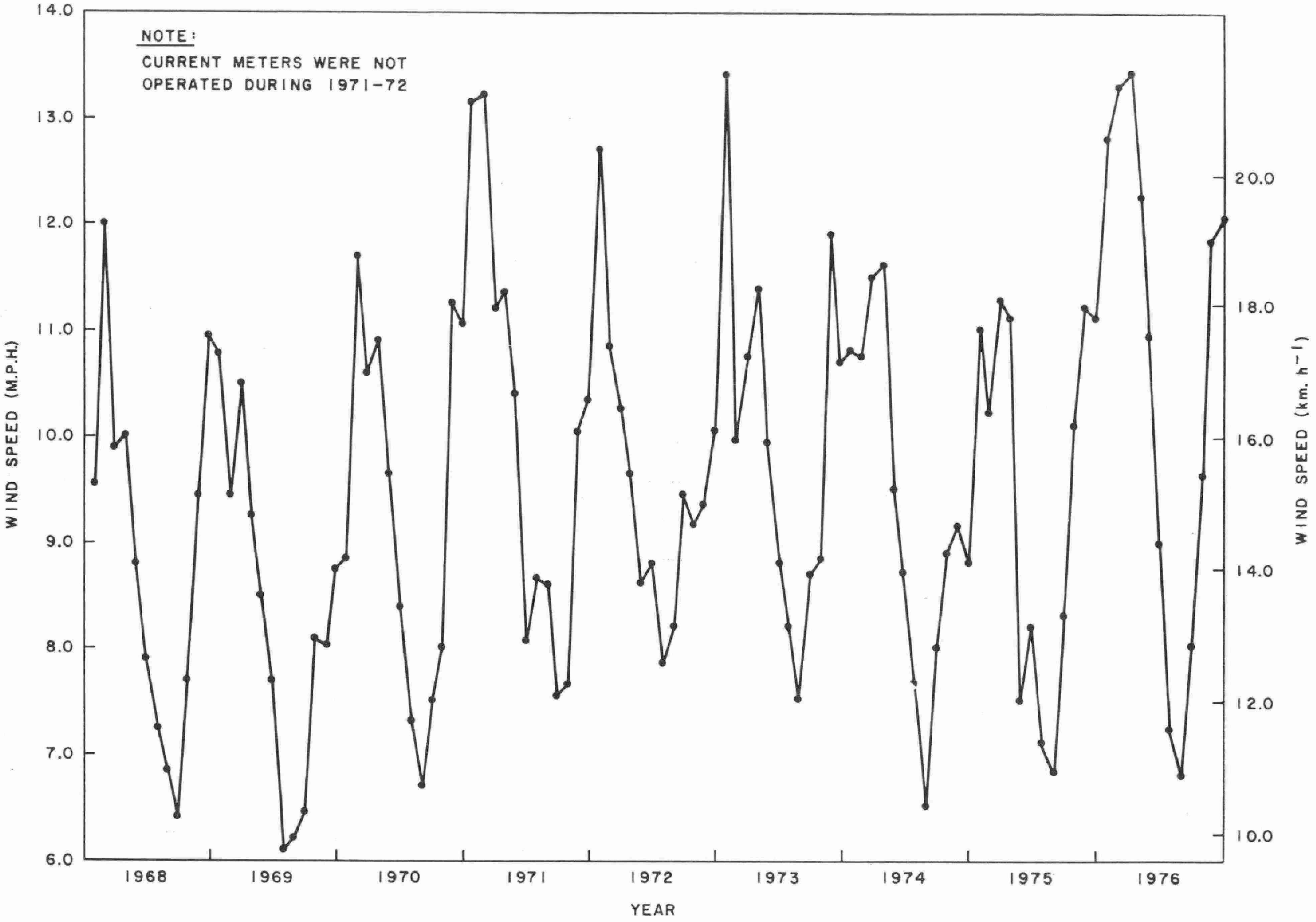


FIGURE 5 - WIND SPEED AT SIMCOE, ONTARIO

APPENDIX 1

INSTRUMENTATION AND DATA ANALYSIS 1976

INSTRUMENT OPERATION

Two geodyne submersible self-recording instruments were operated one on either side of the Stelco dock (see Figure 1) from May 20 to October 19, 1976. Both instruments were laboratory calibrated. They were installed about 2.5 m from bottom in about 7.0 m of water. The instruments had no temperature sensors and therefore, water temperature could not be measured. Current speed and direction averaged over 40 sec were recorded at 20 min interval. At location 176, west of Stelco dock, the propeller of the instrument jammed due to unknown reasons in the early hours of September 1, 1976, and the instrument remained out of operation for the balance of the period.

DATA ANALYSIS

As in the previous years, the data were numerically smoothed (pre-whitened) after Blackman and Tukey (1959; p. 29, 39, 74) using binomial coefficients after Panofsky and Brier (1968; p. 150). The smoothed data were partitioned into the monthly data sets for easy comparison with the earlier results. All data sets were then subjected to statistical analysis to compute two-dimensional frequency of occurrence (current speed and direction). The frequency tables are presented in Tables 1.01 to 1.10. The resultant speed varied from 0.4 to 1.7 cm. s^{-1}, the arithmetic average speed ranged between 1.1 and 4.0 cm. s^{-1}. The persistence factors were 0.23 - 0.69 and the maximum speed recorded was 18.4 cm. s^{-1}.

Current velocities were resolved along north-south and east-west directions and then the hourly averages along the two major directions were computed. The two series of hourly current speeds were subjected to the time series (spectral) analysis by the standard numerical techniques (Kohli, 1978). The Fourier coefficients were smoothed by the Hanning (Blackman and Tukey, 1959; p. 34 and 171). The spectral analysis identifies the variance distribution with respect to time (see Table 4) and therefore provides information on the physical processes responsible for the generation of currents in the study area.

REFERENCES

1. Blackman, R. B., and J. W. Tukey, 1959. The Measurement of Power Spectra. Dover Publications, Inc. New York, 198 p.

2. Kohli, B. 1978. Physical Aspects of Toronto Harbour. 1972-75. Ontario Ministry of the Environment, 135 St. Clair Ave. West., Toronto, Ontario. 50 p.

3. Panofsky, H. A. and G. W. Brier, 1968. Some Applications of Statistics to Meteorology. The Pennsylvania State University, University Park, Pennsylvania.

TABLE 1.01

LOCATION CODE : 1750
AREA : NANTICOKE
LAKE : ERIE

PERIOD : MAY 76
LATITUDE : 80 04 34 W
LONGITUDE : 42 47 05 N

FREQUENCY TABLE

	DIRECTION (COMING FROM) IN DEGREES								
SPEED(CM/S)	337.50- 22.49	22.50- 67.49	67.50- 112.49	112.50- 157.49	157.50- 202.49	202.50- 247.49	247.50- 292.49	292.50- 337.49	ROW SUMS
0.0 -- 0.30	0.0	0.0	0.0	0.88	5.05	4.92	2.15	1.14	14.14
0.31 -- 0.99	0.0	0.0	0.0	0.38	3.41	5.68	4.17	0.0	13.64
1.00 -- 1.99	0.0	0.0	0.0	0.25	4.04	6.69	10.10	1.39	22.47
2.00 -- 2.99	0.0	0.0	0.0	0.0	1.52	4.92	6.44	0.0	12.88
3.00 -- 3.99	0.38	0.0	0.0	0.0	0.88	1.77	5.43	1.64	10.10
4.00 -- 4.99	2.78	0.0	0.0	0.0	0.76	0.76	5.56	1.39	11.24
5.00 -- 7.99	4.29	0.0	0.0	0.0	2.90	1.01	6.57	0.76	15.53
COLUMN SUMS	7.45	0.0	0.0	1.52	18.56	25.76	40.40	6.31	100.00

RESULTANT CURRENT IS	1.69 CM/S AT 261 DEG FROM NORTH	TOTAL NO. READINGS	792
MEAN CURRENT IS	2.45 CM/S	PERSISTENCE IS	0.69
MAXIMUM CURRENT IS	7.94 CM/S	READINGS TAKEN EVERY 20 MIN	

METER OPERATED AT 2.4 M FROM BOTTOM IN 6.7 M OF WATER

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                                        TABLE  1.02


   LOCATION CODE :  1750                                                   PERIOD     :  JUN 75
   AREA          :  NANTICOKE                                              LATTITUDE  : 80 04 34 W
   LAKE          : ERIE                                                    LONGITUDE  : 42 47 05 N

                                      FREQUENCY TABLE
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                             DIRECTION (COMING FROM) IN DEGREES
-----------------------------------------------------------------------------------------------------
   SPEED(CM/S)        337.50-  22.50-  67.50- 112.50- 157.50- 202.50- 247.50- 292.50-
                       22.49   67.49  112.49  157.49  202.49  247.49  292.49  337.49    ROW SUMS
-----------------------------------------------------------------------------------------------------

  0.0  --    0.30      3.94    3.70    4.21    3.52    0.19    0.09    0.05    0.05     15.74
  0.31 --    0.99      1.67    2.45    2.69    3.10    0.93    0.32    0.0     0.42     11.57
  1.00 --    1.99      1.44    1.71    1.16    4.26    1.90    0.88    0.19    1.11     12.64
  2.00 --    2.99      0.14    2.41    1.44    4.26    2.27    1.06    0.51    1.25     13.33
  3.00 --    3.99      0.37    1.30    1.44    3.75    1.99    0.97    0.88    1.30     11.99
  4.00 --    4.99      0.0     0.69    1.76    4.17    1.76    0.60    1.30    0.42     10.69
  5.00 --   12.99      0.37    0.42    3.80   11.81    2.22    2.36    2.36    0.69     24.03

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    COLUMN SUMS        7.92   12.69   16.48   34.86   11.25    6.30    5.28    5.23    100.00
-----------------------------------------------------------------------------------------------------


   RESULTANT CURRENT IS        1.63 CM/S AT  139 DEG FROM NORTH     TOTAL NO. READINGS    2160

   MEAN CURRENT IS             3.22 CM/S                            PERSISTENCE IS        0.50

   MAXIMUM CURRENT IS         12.88 CM/S                            READINGS TAKEN EVERY 20 MIN

                  METER OPERATED AT    2.4 M FROM BOTTOM IN     6.7   M   OF WATER
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                                        TABLE  1.03


    LOCATION CODE :  1750                                                    PERIOD       :  JUL  75
    AREA          :  NANTICOKE                                               LATITUDE     : 80 04 34 W
    LAKE          : ERIE                                                     LONGITUDE    : 42 47 05 N

                                      FREQUENCY TABLE
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                               DIRECTION (COMING FROM) IN DEGREES
 ----------------------------------------------------------------------------------------------------
    SPEED(CM/S)       337.50-  22.50-  67.50- 112.50- 157.50- 202.50- 247.50- 292.50-
                       22.49   67.49  112.49  157.49  202.49  247.49  292.49  337.49       ROW SUMS
 ----------------------------------------------------------------------------------------------------

   0.0   --    0.30    0.67    0.63    0.81    0.72    0.04    0.04    1.39    1.97      6.27
   0.31  --    0.99    0.27    0.85    1.48    0.49    0.36    0.76    0.94    1.61      6.77
   1.00  --    1.99    1.57    1.79    1.39    0.72    1.39    1.43    1.57    3.32     13.17
   2.00  --    2.99    2.69    3.27    1.08    1.34    1.61    1.84    1.84    3.23     16.89
   3.00  --    3.99    1.84    2.82    1.39    1.30    1.25    3.14    2.51    5.42     19.67
   4.00  --    4.99    2.06    1.88    0.94    0.90    0.90    2.82    2.51    1.79     13.80
   5.00  --   12.99    1.75    3.36    1.61    1.39    2.06    5.33    5.38    2.55     23.43

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    COLUMN SUMS       10.84   14.61    8.69    6.85    7.62   15.37   16.13   19.89    100.00
 ----------------------------------------------------------------------------------------------------


    RESULTANT CURRENT IS         0.79 CM/S AT  283 DEG FROM NORTH     TOTAL NO. READINGS    2232

    MEAN CURRENT IS              3.49 CM/S                            PERSISTENCE IS        0.23

    MAXIMUM CURRENT IS          12.75 CM/S                            READINGS TAKEN EVERY 20 MIN

                         METER OPERATED AT    2.4 M FROM BOTTOM IN   6.7  M  OF WATER
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TABLE 1.04

LOCATION CODE : 1750
AREA : NANTICOKE
LAKE : ERIE

PERIOD : AUG 75
LATTITUDE : 80 04 34 W
LONGITUDE : 42 47 05 N

FREQUENCY TABLE

	DIRECTION (COMING FROM) IN DEGREES								
SPEED(CM/S)	337.50- 22.49	22.50- 67.49	67.50- 112.49	112.50- 157.49	157.50- 202.49	202.50- 247.49	247.50- 292.49	292.50- 337.49	ROW SUMS
0.0 -- 0.30	1.39	2.11	2.51	2.87	1.25	1.75	1.43	1.30	14.61
0.31 -- 0.99	2.69	1.48	1.08	1.12	1.08	1.03	0.76	1.79	11.02
1.00 -- 1.99	4.30	2.96	1.34	0.99	2.02	1.43	1.30	3.45	17.79
2.00 -- 2.99	3.76	3.23	0.76	0.67	1.70	1.21	1.93	3.18	16.44
3.00 -- 3.99	2.28	1.34	0.49	0.13	1.30	1.61	2.11	2.60	11.87
4.00 -- 4.99	1.48	0.81	0.18	0.22	1.08	1.75	1.30	2.24	9.05
5.00 -- 10.99	3.45	2.11	1.16	1.03	3.54	2.28	2.15	3.49	19.22
COLUMN SUMS	19.35	14.02	7.53	7.03	11.96	11.07	10.98	18.06	100.00

RESULTANT CURRENT IS 0.70 CM/S AT 312 DEG FROM NORTH

TOTAL NO. READINGS 2232

MEAN CURRENT IS 2.82 CM/S

PERSISTENCE IS 0.25

MAXIMUM CURRENT IS 10.44 CM/S

READINGS TAKEN EVERY 20 MIN

METER OPERATED AT 2.4 M FROM BOTTOM IN 6.7 M OF WATER

TABLE 1.05

LOCATION CODE : 1750
AREA : NANTICOKE
LAKE : ERIE

PERIOD : SEP 75
LATITUDE : 80 04 34 W
LONGITUDE : 42 47 05 N

FREQUENCY TABLE

DIRECTION (COMING FROM) IN DEGREES

SPEED(CM/S)	337.50- 22.49	22.50- 67.49	67.50- 112.49	112.50- 157.49	157.50- 202.49	202.50- 247.49	247.50- 292.49	292.50- 337.49	ROW SUMS
0.0 -- 0.30	1.02	1.57	1.25	1.02	0.51	0.05	0.28	0.05	5.74
0.31 -- 1.99	2.55	3.61	1.85	2.08	2.27	1.53	0.97	2.92	17.78
2.00 -- 3.99	4.91	3.66	1.25	1.34	4.31	4.91	3.43	5.93	29.72
4.00 -- 5.99	6.16	4.12	1.34	1.02	3.61	2.96	3.10	3.24	25.56
6.00 -- 7.99	2.45	1.57	0.79	0.88	1.67	1.11	1.67	2.31	12.45
8.00 -- 9.99	1.39	2.13	0.37	0.28	0.65	0.37	0.19	1.16	6.53
10.00 -- 18.99	0.56	0.83	0.51	0.0	0.0	0.0	0.09	0.23	2.22
COLUMN SUMS	19.03	17.50	7.36	6.62	13.01	10.93	9.72	15.83	100.00

RESULTANT CURRENT IS 0.99 CM/S AT 346 DEG FROM NORTH

TOTAL NO. READINGS 2160

MEAN CURRENT IS 4.04 CM/S

PERSISTENCE IS 0.24

MAXIMUM CURRENT IS 18.44 CM/S

READINGS TAKEN EVERY ** MIN

METER OPERATED AT 2.4 M FROM BOTTOM IN 6.7 M OF WATER

TABLE 1.06

LOCATION CODE : 1750
AREA : NANTICOKE
LAKE : ERIE

PERIOD : OCT 75
LATITUDE : 80 04 34 W
LONGITUDE : 42 47 05 N

FREQUENCY TABLE

	DIRECTION (COMING FROM) IN DEGREES								
SPEED(CM/S)	337.50- 22.49	22.50- 67.49	67.50- 112.49	112.50- 157.49	157.50- 202.49	202.50- 247.49	247.50- 292.49	292.50- 337.49	ROW SUMS
0.0 -- 0.30	1.42	1.12	0.75	1.42	1.57	0.07	0.0	0.0	6.34
0.31 -- 0.99	3.36	1.12	1.04	0.52	1.12	0.52	0.07	0.07	7.83
1.00 -- 1.99	4.25	2.54	1.49	0.97	1.34	2.09	1.34	1.27	15.29
2.00 -- 2.99	4.47	2.39	1.34	1.94	1.64	2.91	0.82	1.27	16.78
3.00 -- 3.99	3.06	1.19	1.34	1.64	1.42	1.34	0.37	0.75	11.11
4.00 -- 4.99	3.28	1.12	1.79	0.89	1.04	0.97	0.52	0.75	10.37
5.00 -- 13.99	4.92	10.29	5.52	2.68	0.89	2.39	2.31	3.28	32.29
COLUMN SUMS	24.76	19.76	13.27	10.07	9.02	10.29	5.44	7.38	100.00

RESULTANT CURRENT IS 1.34 CM/S AT 40 DEG FROM NORTH

TOTAL NO. READINGS 1341

MEAN CURRENT IS 3.78 CM/S

PERSISTENCE IS 0.35

MAXIMUM CURRENT IS 13.19 CM/S

READINGS TAKEN EVERY ** MIN

METER OPERATED AT 2.4 M FROM BOTTOM IN 6.7 M OF WATER

TABLE 1.07

LOCATION CODE : 1760
AREA : NANTICOKE
LAKE : ERIE

PERIOD : MAY 76
LATTITUDE : 80 04 56 W
LONGITUDE : 42 46 58 N

FREQUENCY TABLE

	DIRECTION (COMING FROM) IN DEGREES								
SPEED(CM/S)	337.50- 22.49	22.50- 67.49	67.50- 112.49	112.50- 157.49	157.50- 202.49	202.50- 247.49	247.50- 292.49	292.50- 337.49	ROW SUMS
0.0 -- 0.30	11.24	0.51	1.01	0.76	3.91	2.78	4.80	8.96	33.96
0.31 -- 0.99	9.60	0.51	0.76	1.26	3.66	1.01	3.54	4.67	25.00
1.00 -- 1.99	9.97	0.25	0.25	0.63	1.26	0.76	2.78	1.52	17.42
2.00 -- 2.99	7.20	1.52	0.0	0.0	0.51	0.51	1.39	1.26	12.37
3.00 -- 3.99	4.42	0.38	0.0	0.0	0.0	0.25	1.77	1.14	7.95
4.00 -- 4.99	2.15	0.38	0.0	0.0	0.0	0.0	0.13	0.0	2.65
5.00 -- 6.99	0.38	0.25	0.0	0.0	0.0	0.0	0.0	0.0	0.63
COLUMN SUMS	44.95	3.79	2.02	2.65	9.34	5.30	14.39	17.55	100.00

RESULTANT CURRENT IS 0.77 CM/S AT 345 DEG FROM NORTH

TOTAL NO. READINGS 792

MEAN CURRENT IS 1.13 CM/S

PERSISTENCE IS 0.68

MAXIMUM CURRENT IS 6.25 CM/S

READINGS TAKEN EVERY 20 MIN

METER OPERATED AT 2.4 M FROM BOTTOM IN 7.3 M OF WATER

TABLE 1.08

LOCATION CODE : 1760
AREA : NANTICOKE
LAKE : ERIE

PERIOD : JUN 75
LATITUDE : 80 04 56 [illegible]
LONGITUDE : 42 46 58 N

FREQUENCY TABLE

SPEED(CM/S)	DIRECTION (COMING FROM) IN DEGREES								
	337.50- 22.49	22.50- 67.49	67.50- 112.49	112.50- 157.49	157.50- 202.49	202.50- 247.49	247.50- 292.49	292.50- 337.49	ROW SUMS
0.0 -- 0.30	1.85	0.60	3.47	2.08	2.73	5.14	8.94	4.12	28.94
0.31 -- 0.99	2.41	0.97	2.50	1.25	2.22	2.87	5.28	1.76	19.26
1.00 -- 1.99	3.61	1.71	1.81	1.62	1.62	2.64	3.43	1.34	17.78
2.00 -- 2.99	3.70	1.90	2.22	0.69	0.83	2.08	1.99	1.39	14.81
3.00 -- 3.99	1.94	1.39	1.94	0.32	0.28	1.02	1.11	1.20	9.21
4.00 -- 4.99	0.51	0.46	1.48	0.09	0.23	0.23	0.32	0.65	3.98
5.00 -- 11.99	0.32	0.79	4.03	0.19	0.14	0.0	0.05	0.51	6.02
COLUMN SUMS	14.35	7.82	17.45	6.25	8.06	13.98	21.11	10.97	100.00

RESULTANT CURRENT IS 0.38 CM/S AT 43 DEG FROM NORTH

TOTAL NO. READINGS 2160

MEAN CURRENT IS 1.64 CM/S

PERSISTENCE IS 0.23

MAXIMUM CURRENT IS 11.25 CM/S

READINGS TAKEN EVERY 20 MIN

METER OPERATED AT 2.4 M FROM BOTTOM IN 7.3 M OF WATER

TABLE 1.09

LOCATION CODE : 1760
AREA : NANTICOKE
LAKE : ERIE

PERIOD : JUL 75
LATTITUDE : 80 04 56 W
LONGITUDE : 42 46 58 N

FREQUENCY TABLE

	DIRECTION (COMING FROM) IN DEGREES								
SPEED(CM/S)	337.50- 22.49	22.50- 67.49	67.50- 112.49	112.50- 157.49	157.50- 202.49	202.50- 247.49	247.50- 292.49	292.50- 337.49	ROW SUMS
0.0 -- 0.30	1.57	2.60	3.45	0.85	2.11	3.23	4.30	2.02	20.12
0.31 -- 0.99	1.61	4.48	3.32	0.40	0.94	3.99	2.78	1.61	19.13
1.00 -- 1.99	1.52	4.93	4.84	0.81	0.54	3.99	2.37	0.85	19.85
2.00 -- 2.99	0.67	4.12	6.81	0.63	0.67	2.15	1.79	0.22	17.07
3.00 -- 3.99	0.27	2.11	4.17	0.54	0.27	0.76	0.76	0.09	8.96
4.00 -- 4.99	0.13	0.94	4.26	0.36	0.0	0.09	0.36	0.09	6.23
5.00 -- 15.99	0.04	0.58	7.48	0.13	0.22	0.0	0.18	0.0	8.65
COLUMN SUMS	5.82	19.76	34.32	3.72	4.75	14.20	12.54	4.88	100.00

RESULTANT CURRENT IS 1.15 CM/S AT 83 DEG FROM NORTH

TOTAL NO. READINGS 2232

MEAN CURRENT IS 2.02 CM/S

PERSISTENCE IS 0.57

MAXIMUM CURRENT IS 15.69 CM/S

READINGS TAKEN EVERY 20 MIN

METER OPERATED AT 2.4 M FROM BOTTOM IN 7.3 M OF WATER

TABLE 1.10

LOCATION CODE : 1760
AREA : NANTICOKE
LAKE : ERIE

PERIOD : AUG 75
LATITUDE : 80 04 56 W
LONGITUDE : 42 46 58 N

FREQUENCY TABLE

	DIRECTION (COMING FROM) IN DEGREES								
SPEED(CM/S)	337.50- 22.49	22.50- 67.49	67.50- 112.49	112.50- 157.49	157.50- 202.49	202.50- 247.49	247.50- 292.49	292.50- 337.49	ROW SUMS
0.0 -- 0.30	0.22	3.23	3.00	2.55	4.08	2.20	11.92	1.16	28.36
0.31 -- 0.99	0.99	1.79	2.24	1.48	1.70	1.16	0.67	0.54	10.57
1.00 -- 1.99	2.51	5.11	4.75	1.93	1.52	1.12	2.51	1.03	20.47
2.00 -- 2.99	3.58	4.66	3.94	1.03	0.49	0.58	1.57	0.72	16.58
3.00 -- 3.99	1.03	2.82	3.58	0.40	0.18	0.31	0.45	0.31	9.09
4.00 -- 4.99	0.36	1.84	3.23	0.09	0.0	0.22	0.09	0.04	5.87
5.00 -- 14.99	0.04	1.70	6.72	0.13	0.18	0.22	0.0	0.04	9.05
COLUMN SUMS	8.74	21.15	27.46	7.62	8.15	5.82	17.20	3.85	100.00

RESULTANT CURRENT IS 1.25 CM/S AT 69 DEG FROM NORTH

TOTAL NO. READINGS 2232

MEAN CURRENT IS 1.95 CM/S

PERSISTENCE IS 0.64

MAXIMUM CURRENT IS 14.88 CM/S

READINGS TAKEN EVERY 20 MIN

METER OPERATED AT 2.4 M FROM BOTTOM IN 7.3 M OF WATER

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